Studying the hybrid pulsator 12 Lacertae: mode identification and complex seismic modelling

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Abstract We present identification of the mode degree, ℓ, for all observed frequencies of 12 Lac and results of seismic modelling which consists in fitting simultaneously the centroid mode frequencies and the corresponding values of the complex nonadiabatic f-parameter. Effects of chemical composition, opacities, core overshooting and non-LTE atmospheres were taken into account.

1 Mode identification

12 Lac is the early B-type pulsator in which at least ten frequencies of the β Cep type and one of the SPB type are excited. To determine the pulsation mode degree, ℓ, we made use of the amplitudes and phases in the Strömgren *uvy* photometric passbands [5] as well as the radial velocity data [4]. Two approaches were used: the first one with the theoretical f-parameter [2] and the second one with the empirical values of f [3]. The LTE [6] and non-LTE [7] stellar atmosphere models were included. We were able to find identification for five strongest modes and limitation on ℓ for the others. The dominant mode ν_1 as well as ν_2 are certainly the dipole modes. Identification of ν_3 and ν_5 is also unique, they are quadruple modes, and ν_4 is a radial mode. The high-order g-mode is the dipole.

2 Seismic models of 12 Lac

We managed to construct models fitting simultaneously the two frequencies, ν_4 (the radial p_1 mode) and ν_2 (the dipole g_1 mode), and the corresponding values of the

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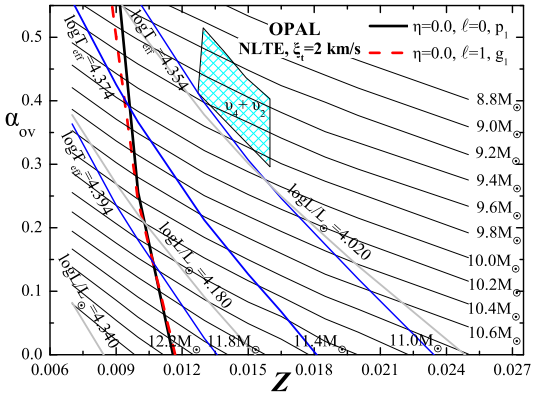

Fig. 1 The OPAL seismic models of 12 Lac fitting ν_2 and ν_4 on the $Z - \alpha_{ov}$ plane. The hatched area indicates models fitting the empirical $f-$parameter, simultaneously for ν_4 and ν_2. The empirical values of f were calculated with the NLTE atmospheres.

f-parameters. This approach is called complex asteorseismology and yields more information on model and theory. Calculations were performed in a wide range of metallicity, overshooting parameter from the convective core as well as for different stellar atmosphere models: LTE with the microturbulent velocity of 2 and 8 km/s, and NLTE with 2 km/s. We used the OPAL and OP opacity data, and the AGSS09 chemical mixture [1]. All effects of rotation were ignored. In Fig. 1, we give an example of seismic models obtained with the OPAL data on the $Z - \alpha_{ov}$ plane.

3 Conclusions

Mode identification with the LTE and non-LTE atmospheres provided similar results. Comparison of the empirical and theoretical values of the nonadiabatic f-parameter allowed us to determine the radial order of the radial mode ν_4. Clearly, ν_4 is the fundamental mode. With both opacity data we were able to construct seismic models fitting the ν_4 and ν_2 frequencies and the corresponding f-parameters. Moreover, models fitting the high-order g-mode frequency and reproducing its value of f were found. No preferences for any opacity tables were obtained.

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